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ORIGINAL RESEARCH

# POSTURAL STABILITY AND KINETIC CHANGE IN SUBJECTS WITH PATELLOFEMORAL PAIN AFTER A NINE-WEEK HIP AND CORE STRENGTHENING INTERVENTION

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## ABSTRACT

***Background:*** Idiopathic patellofemoral pain (PFP) has been linked to hip weakness and abnormal lower extremity mechanics. The effect of a strengthening intervention on balance has not been well studied among individuals with PFP.

***Hypothesis/Purpose:*** The primary aim of this study was to evaluate changes in center of pressure displacement during the single limb squat following a nine-week physical therapy intervention among adolescent females with PFP.

***Study Design:*** Interventional and cross-sectional

***Methods:*** Seven adolescent females with PFP (10 extremities) were included in the study. Center of Pressure (CoP) excursions during a single limb squat task were measured before and after a nine week of physical therapy intervention focused on strengthening of the hip and core. Seven asymptomatic females were matched to the PFP group on the basis of age and activity level, and were tested as a reference group. CoP trajectories were reduced into four variables: mean distance (MDIST), root-mean-square distance (RDIST), range (RANGE), and 95% confidence interval circle area (AREA-CC). Maximum knee flexion angle, peak knee power generation and absorption were also recorded. Linear mixed models were used to test for within and between group differences in CoP metrics.

***Results:*** Pre-intervention, CoP range, knee power absorption and generation were significantly decreased in the PFP group relative to the reference group. Post-intervention, the PFP group reported a significant decrease in symptom severity. There was also a significant ($p < 0.05$) increase in MDIST, RDIST, RANGE, AREA-CC, peak knee flexion angle, peak power absorption and power generation. There was no difference ($p > 0.05$) in knee flexion, knee power or CoP displacement between the two groups after the physical therapy intervention.

***Conclusion:*** Hip and core-strengthening resulted in a significant decrease in symptom severity as well as significant reductions in CoP displacement.

***Level of Evidence:*** 3

***Key words:*** Balance, hip strength, patellofemoral pain syndrome, postural stability

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## INTRODUCTION

Hip weakness and subsequent abnormal lower extremity mechanics may contribute to the development of Idiopathic Patellofemoral Pain (PFP).[1,2] Poor control of the femur during weight bearing tasks is believed to alter the kinematics of the knee joint, leading to joint dysfunction and pain.[3-5] Furthermore, hip muscles are integral in proper lower extremity mechanics and are especially important during single limb tasks.[6]

The single limb squat (SLS) has been used as an assessment of lower extremity mechanics and strength.[7] Previous authors suggest adequate hip and core strength may help to minimize unnecessary femoral and pelvic motion during this task.[6] Excessive motion of the trunk, pelvis and femur may make balance more challenging during any single limb support task, so measuring balance performance during the SLS may reveal proximal weakness and excessive compensatory movements during this maneuver.

Center of pressure (CoP) displacement during dynamic tasks has been used to assess balance and postural stability in many studies.[8-11] For a task such as SLS, CoP measures may be used to evaluate how the subject prepares and responds to anticipated movements.[12,13] The CoP represents the instantaneous point of application of the ground reaction force vector (GRF) in the plane of the supporting surface during weight bearing, and its time history or trajectory reflects a subject's ability to maintain balance. People may use different strategies to control their posture that may reflect their available strength, balance, coordination, and/or body mechanics.

The primary aim of this study was to evaluate changes in center of pressure displacement during the single limb squat following a nine-week physical therapy intervention among adolescent females with PFP. The authors hypothesized that a hip-strengthening intervention would result in changes in center of pressure displacement during a single limb squat task.

## METHODS

### Participant Selection

Seven young females between the ages of 12 and 18 diagnosed with PFP were recruited from our institution's Sports Medicine Clinics. The inclusion criteria were unilateral or bilateral PFP without history of any prior acute trauma to the lower extremity, and a history of an insidious onset of activity related pain for one to six months during two or more of the following activities: exercise/athletics, prolonged sitting for greater than one hour, ascending/descending stairs, squatting or kneeling. The diagnosis of idiopathic patellofemoral pain was confirmed by a fellowship trained, board certified, pediatric sports medicine physician. In subjects with bilateral pain, both legs were tested. A total of 10 symptomatic legs (three subjects were affected by bilateral PFP and four subjects were affected by unilateral PFP) were included in the symptomatic group.

Based on the demographics of each subject in the symptomatic group, seven young females without any history of knee pathology and/or knee pain were individually recruited to serve as the reference group. For analysis, the reference subjects were matched to the symptomatic subjects on the basis of age (difference < seven months). For matching purposes, a total of 10 limbs were included in the reference group. Table 1 lists the descriptive characteristics of all subjects. The study was approved by the Colorado Multi-Institutional Review Board. All subjects and parents reviewed and signed an informed consent form before participating in any study related procedures.

### Study Procedures

Symptomatic subjects reported to one of two sports medicine trained physical therapists (Sport Certified Specialists) for a comprehensive physical examination. During this visit, the symptomatic subjects were given an individualized exercise prescription and formal instruction on how to properly complete the home physical therapy program (Appendix 1). Completion of the physical therapy intervention consisted of progression from open kinetic chain exercises (3-4 times per week), to closed kinetic chain exercises (3-4 times per week), to functional exercises that emphasized dynamic hip and core movement patterns (3-4 times per week). All home based exercises were selected based on functional anatomy of muscle actions as well as their previous utilization in related research.[14,15] The parameters of intensity and duration were derived from basic exercise physi-

**Table 1.** *Characteristics of the participants*

| | Symptomatic Group | Reference Group | P value |
|---|---|---|---|
| Age (yrs) | 14.20 ± 0.75 | 14.12 ± 0.86 | 0.6543 |
| Tegner Activity Level | 6.43 ± 2.99 | 7.43 ± 1.51 | 0.2753 |
| BMI (kg/m$^2$) | 17.40 ± 2.87 | 18.40 ± 3.21 | 0.8024 |

ology principles with parameters for strengthening and neuromuscular adaptation.[16] The repetitions/hold time, sets and frequency were individually prescribed for each patient by the PT. Progression was assessed and adjusted during a weekly physical therapy visit. The foundation of the intervention was adapted from a hip and core strengthening intervention initially described by Mascal and Powers.[15]

Symptom severity and knee function were assessed with the Anterior Knee Pain Symptom Scale (AKPS), Visual Analogue Scale for Worst (VAS-W) and Visual Analogue Scale for Usual pain over the past week (VAS-U)[17-19] at the time of their pre-testing assessment. Within two weeks of this assessment, subjects reported to our laboratory and performed a SLS on two Bertec strain gage force platforms (Model 4060-10). Subjects started the squat maneuver in a closed chain position with one foot on each force platform. Subjects were instructed to stand on one foot with arms in a self-selected position and at a self-selected tempo, squat down without losing balance to a comfortable degree of knee flexion, and then return to an upright position. During this task, the torso position was to remain vertical without forward trunk flexion, the foot was to remain flat on the force platform or as close to flat as possible, and subjects were not allowed to support themselves on any stationary fixture. All subjects were given a chance to practice this maneuver five times before data were collected during five complete repetitions. Due to concerns regarding pain intensity, subjects were only required to squat to tolerance. One complete repetition was defined as max knee extension to max knee extension. All trials in which a subject lost balance and subsequently put both feet down were excluded from the analysis.

The single limb squat task was selected because it simulates a common athletic position[6] and because the increased knee flexion angles achieved during the task simulate movement patterns (stair ascent/descent) known to exacerbate knee pain symptoms. Proper execution of the task requires adequate lower extremity strength and neuromuscular control. Each individual subject's pattern of CoP displacement during the SLS represents their ability to maintain balance during a challenging, functional movement pattern.[12,13]

Prior to testing, 14 mm diameter retroreflective markers were placed on lower extremity bony landmarks, identified by palpation by one physical therapist with greater than five years of experience in a clinical movement analysis laboratory. The maker set was a modified version of the Helen Hayes marker set that includes the ten lower extremity markers described by Kadaba et al [20] in addition to markers (medial femoral condyle and medial malleolus) that were utilized during the static calibration trial only. Marker trajectory data were recorded at 120 Hz using a thirteen camera Vicon MX motion capture system. Analog data from the two Bertec force platforms were collected at a frequency of 1080Hz. Vicon Nexus™ was used to process all motion capture data and a conventional gait model (Vicon Plug-in-Gait™) was used to generate kinematics, kinetics and CoP, which were time normalized to the duration of the task. All kinetic measures were normalized to each subject's body weight. Data were then imported into a custom Matlab (The MathWorks Inc., Natwick, MA, USA) program, which extracted peak knee flexion, peak power absorption, peak power generation, and Center of Pressure trajectory during the SLS. For all subjects, the same motion capture system, testing procedure and, software programs and processes were used during evaluation of symptomatic subjects, pre- and post-intervention, and the reference group.

The CoP data were reduced according to the equations outlined by Prieto.[21] In order to quantify the CoP movements during the task, the following four measures were used: Mean distance (MDIST): the average distance from the mean CoP; Root-mean-square distance (RDIST): the RMS distance from the mean CoP; Range (RANGE): the maximum distance between any two CoP locations; and 95% confidence interval circle area (AREA-CC): the area of a circle that contains approximately 95% of the distances from the mean CoP. All CoP measures were quantified using Matlab. For each of the CoP variables, the average value from the five trials was used for statistical analysis. Figure 1 shows a sample CoP trajectory from a single limb squat trial. The maximum knee flexion angle, maximum knee power absorption, and maximum knee power generation values achieved during each SLS trials were identified using a custom Matlab program. For each variable, the average value from the five trials was used for statistical analysis.

## STATISTICAL METHODS

Paired, two-tailed, t-tests were used to compare demographics in the two groups as well as changes in VAS-U, VAS-W, and AKPS scores following the physical therapy intervention. A generalized linear regression analysis was used to compare within group (symptomatic group pre- vs. post-intervention) and between group (symptomatic group pre-intervention vs. reference group and symptomatic group post-intervention vs. reference group) differences in CoP measures, knee flexion angles, and knee power. When evaluating within group changes, the unstructured covariance structure was used to account for correlation due to repeated measures (pre- and post-intervention time points). Random intercept models were used to account for the correlation due to the inclusion of multiple limbs from the same subject. All statistical analyses were performed using SAS version 9.3 (SAS Institute Inc., Cary, NC, USA)

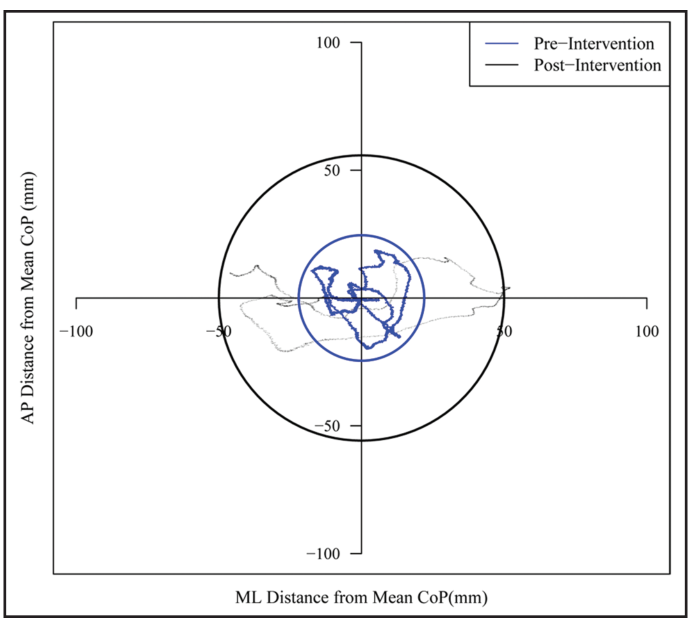


**Figure 1.** *Center of pressure tracing obtained from a symptomatic female subject pre and post intervention. The circles represent an estimate of the area that contains approximately 95% of the distances from the mean CoP.*

## RESULTS

The clinical characteristics associated with the symptomatic and reference groups are listed in Table 1. There was no difference ($p > 0.05$) in age, activity level or BMI between the two groups. After the nine week hip-strengthening intervention, there was a significant decrease in average Anterior Knee Pain Symptom Scale (AKPS), Visual Analogue Scale for Worst Pain (VAS-W) and Visual Analogue Scale for Usual Pain (VAS-U) over the past week (Table 2). The clinical outcomes associated with the intervention (change in hip strength, hip kinematics and symptom severity) were not the focus of this study as they have been previously presented. [22] Although the reduction in symptom severity was not the focus of this manuscript, it has been reported to context for the CoP measurements.

### Pre- vs. post-intervention changes in the symptomatic group

Among subjects in the symptomatic group, there was a significant increase in the following CoP measures after the nine-week hip-strengthening intervention: AREA-CC (mean difference: 2012.88 $mm^2$, 95% CI: 170.31 to 3855.45; p = 0.0347), MDIST (mean difference: 2.72 mm, 95% CI: 0.23 to 5.21; p = 0.0347), RDIST (mean difference: 3.31 mm, 95% CI: 0.67 to 5.96; p = 0.0182) and RANGE (mean difference: 12.62 mm, 95% CI: 5.37 to 19.87; p = 0.0026). There

**Table 2.** *Improvements in symptom severity following the intervention*

| | Mean Difference | 95% CI | P value |
|---|---|---|---|
| AKPS | 13.86 | 8.82 to 21.89 | 0.0056 |
| VAS-W | 48.29 | 16.53 to 80.05 | 0.0098 |
| VAS-U | 52.14 | 42.12 to 62.17 | <0.0001 |

AKPS = Anterior knee pain scale; VAS-W = visual analogue scale for worst pain over the past week; VAS-U = visual analogue scale for usual pain over the past week.

was also a significant increase in peak knee flexion angle [mean difference: 8.04°, 95% CI: 4.25 to 11.84°, p = 0.0006], peak power generation [mean difference: 0.49 W/Kg), 95% CI: 0.21 to 0.78; p = 0.0025] and peak power absorption [mean difference: 0.49 W/Kg, 95% CI: 0.01to 0.96, p = 0.044].

**Reference group vs. symptomatic group pre-intervention**

Prior to the intervention, peak power absorption, peak power generation and CoP range were significantly different between the symptomatic and reference groups. Peak power absorption during the single limb squat was an average of 0.92 W/Kg (95% CI: 0.45 to 1.38 W/Kg; p = 0.0029) higher in the reference group. Peak power generation was an average of 0.87 W/Kg (95% CI: 0.32 to 1.41 W/Kg, p = 0.0081) higher in the reference group. CoP range was higher in the reference group than the symptomatic group by an average of 7.73 mm (95% CI: 0.47 to 14.99, p = 0.0403). There was no significant difference in AREA-CC (p = 0.4162), MDIST (p = 0.1359), RDIST (p = 0.1066), or peak knee flexion angle (p = 0.8114).

**Reference group vs. symptomatic group post-intervention**

After the physical therapy intervention, there was no significant difference in peak power absorption (p = 0.1019]) peak power generation (p = 0.3324) or CoP range (p = 0.3708) between groups. Similarly, there was no significant difference between groups with respect to AREA-CC (p = 0.4057), MDIST (p = 0.4668), RDIST (p = 0.4967) or peak knee flexion angle (p = 0.2893). See Figures 2-3 for more information about the between and within group differences in peak knee flexion, peak knee power and the CoP measures.

## DISCUSSION

CoP displacement, represents the subject's response to internal and external perturbations during a given task.[13,23] Compared to CoP measures during static tasks, CoP measures during dynamic tasks are a better discriminator of injured versus un-injured populations.[10,24] Therefore, the primary purpose of this study was to assess CoP displacement during a single limb squat (SLS) among subjects with idiopathic PFP before and after a hip and core strengthening intervention Following the nine-week intervention, the symptomatic group self-reported a significant reduction in symptom severity. The subjects also demonstrated a significant increase in CoP area, range, mean distance and root mean square distance. Together, these results provide some evidence that increased postural stability may be representative of a positive clinical outcome following PFP interventions.

Prior to the physical therapy intervention, the symptomatic subjects demonstrated a lower COP range relative to the reference group. Following the intervention, there was no longer a significant difference in CoP range between groups (Figure 2). The trend towards decreased CoP displacement among symptomatic subjects prior to the intervention contradicts the CoP measures reported by Lee et al[24] in a case control study of subjects with and without PFP. In their study, subjects with PFP demonstrated significantly increased peak and mean medial-lateral CoP displacements during a single limb step-down task compared to the reference group. However, Lee et al[24] used a metronome to control the cadence of the single limb task used in their study. By imposing a temporal constraint, the task demands are likely to change and thus, CoP excursions reported in the present study may not be directly comparable to CoP measures observed by Lee et al.[24] Paterno et al[25] assessed the biomechanics of 56 athletes that underwent anterior cruciate ligament reconstruction. Within 12 months of the evaluation, 13 (23%) of the athletes suffered a repeat ACL tear. Postural stability (average degree of deflection on the overall stability score as measured by the Biodex stability system), transverse plane hip moment, coronal plane knee range of motion, and sagittal plane knee moment were all significantly related to re-injury risk in the multivariable model. A deficit (increase) in unilateral postural sway during quiet standing was associated with increased likelihood of ACL re-injury (OR: 2.3, 95% CI: 1.1 to 4.7].

The results of the current study are consistent with a prospective study of a cohort of female soccer players.[26] After controlling for other significant variables, Soderman et al[26] demonstrated that a low postural sway was associated with a significantly greater risk for a lower extremity injury during the course of the soccer season. The design of the current study was unique in that CoP measures were evaluated before

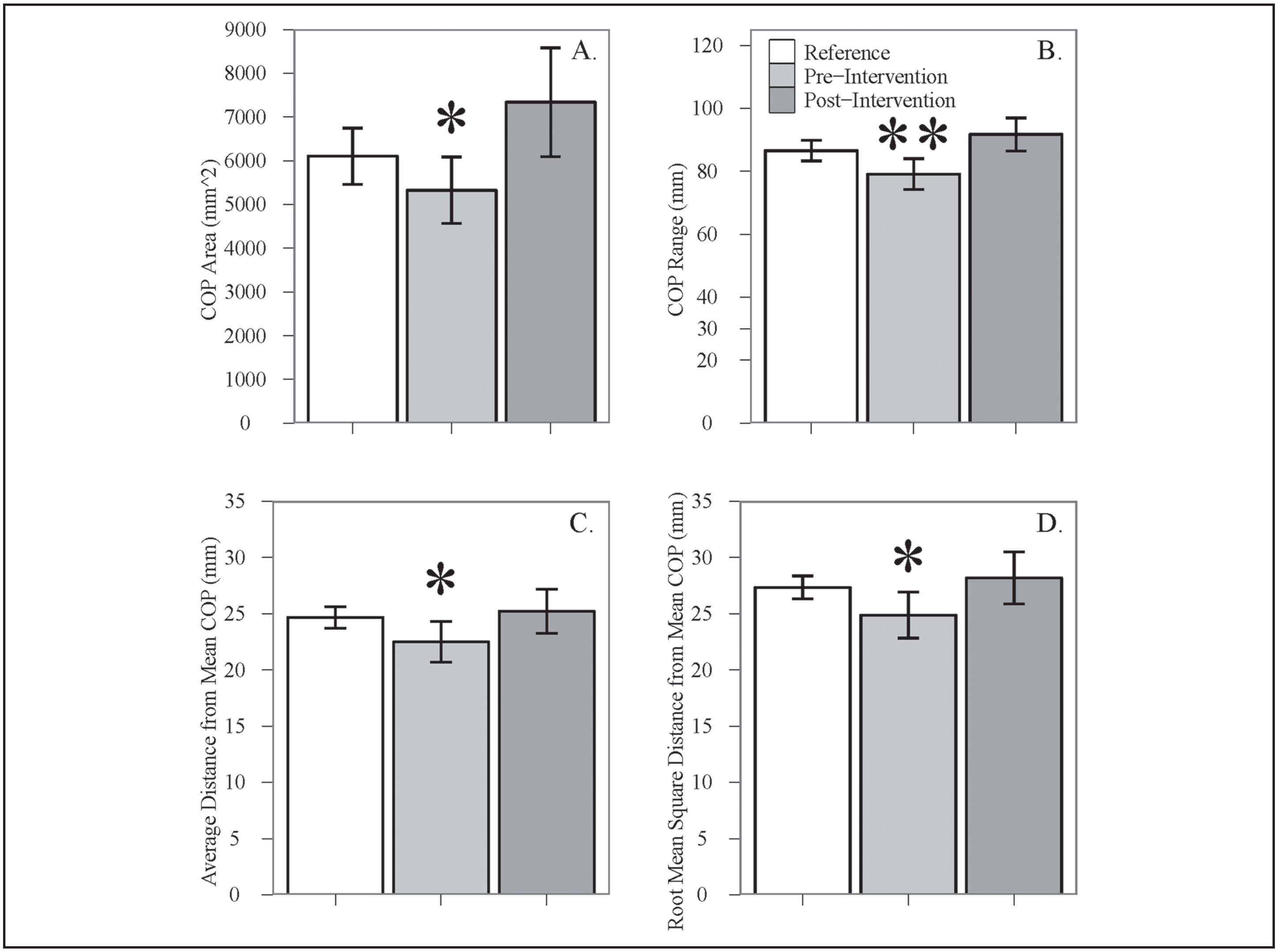


**Figure 2.** *Comparison of Variables Derived from CoP Measures.*Significantly (p < 0.05) different from post-intervention evaluation. **Significantly (P < 0.05) different from post-intervention evaluation and reference group.*

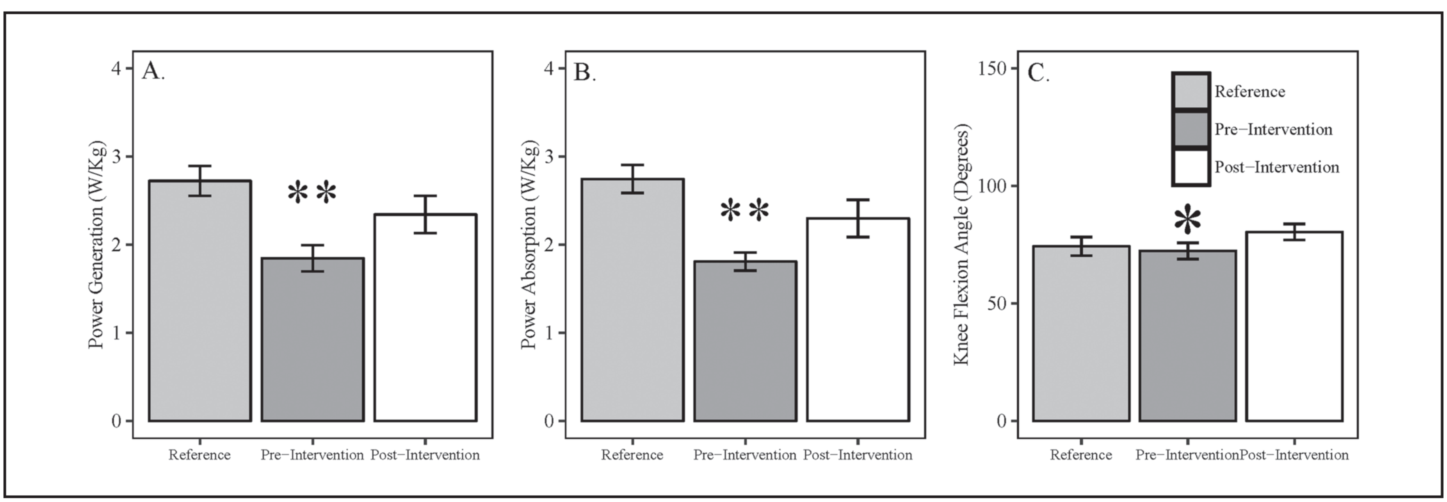


**Figure 3.** *Comparison of Peak Knee Power and Peak Knee Flexion.*Significantly (p < 0.05) different from post-intervention evaluation. **Significantly (P < 0.05) different from post-intervention evaluation and reference group.*

and after a hip strengthening intervention. Following the nine-week intervention, dramatic improvements in the symptom severity were achieved according the VAS-W, VAS-U and AKPS. Symptomatic relief was accompanied by a significant increase in CoP area, range, mean distance and root mean square distance. Increased CoP displacement following the intervention may be due to increased joint proprioception, due to an emphasis on hip and core strengthening during the intervention, and/or greater torque production at the hip joint. Along with improvements in stability, the subjects appeared to challenge themselves to a greater degree after the intervention. This was evidenced by an increase in peak knee flexion, peak knee power and peak knee absorption during the SLS. It is unclear, however, whether the changes in performance are due to improvements in neuromuscular control and strength or are due to the absence of pain during the task. Future research is needed to determine whether measures of CoP displacement such as area, range, MDIST, and RDIST are predictive of the onset of PFP in previously asymptomatic populations.

The peak (or maximum) knee flexion angle achieved during SLS is one of the measures used to subjectively evaluate symptomatic patients. Due to the fact that subjects with PFP routinely report the presence of pain during activities that involve increased knee flexion angles, such as stair ascent/descent,[3] the authors of this study believe it is fair to assume that pain will limit the amount of knee flexion that is achieved during this task. Peak knee flexion angle was significantly higher in in the reference group compared to the symptomatic subjects prior to the intervention suggesting that pain may have limited the magnitude of knee flexion observed among the symptomatic subjects. Following the physical therapy intervention, there were no significant differences in the knee flexion angles between the reference and symptomatic groups. This suggests that the symptomatic subjects may have returned to a more normal peak knee flexion angle after the intervention. Peak power generation and peak power absorption, on the other hand, were significantly higher in the reference group prior to the intervention and were not significantly different after the intervention between the groups. As power is calculated from joint torque and angular velocity, this suggests that the PFP subjects after the intervention were completing the task faster and/or with higher force. This supports the use of kinetic recordings to obtain metrics such as power and CoP displacement, rather than simply subjectively assessing knee joint angles.

There are several limitations to the study. Financial constraints limited the number of subjects the authors enrolled in this preliminary study. Comparisons of symptomatic and reference subjects were limited by the small sample size. Additionally, performance during single limb squat task was self-selected. Changes in postural stability following the intervention may have been related to the maximum knee flexion angle achieved during the task and/or changes in deceleration and acceleration during the downward and upward phases of the task, respectively. Future research should evaluate performance during a standardized version of the single limb squat test. Finally, individuals in the reference group were not re-tested and intervention was not randomized. It is not possible to assess causal relationship between hip therapy intervention, symptom severity, and increased postural stability. The possibility that changes in symptom severity and balance in the symptomatic group may have been due to greater familiarization with the task and/or the passing of time cannot be excluded based on this study alone.

## CONCLUSION

At the beginning of this study, subjects with PFP demonstrated significantly decreased CoP range, peak knee power absorption and peak knee power generation relative to an asymptomatic reference group. Following a nine-week hip and core strengthening intervention, symptomatic improvements were accompanied by significant improvements in CoP excursions, peak knee power, and peak knee flexion angles. The results of the study suggest that changes in balance can be achieved in a population of subjects affected by PFP following a hip and core strengthening intervention. Furthermore, CoP measures may be an effective tool for assessing progression during a PT intervention designed to alleviate pain through improvements in lower extremity strength and neuromuscular control. Additional prospective cohort studies are needed to determine whether the CoP displacement measures used in this study during a single limb squat are also significantly predictive of the onset of PFP in previously asymptomatic populations.

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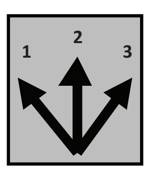
**Appendix 1.** *Individualized exercise prescription and progression by phases*

| | Exercise | Description | Reps/Sets |
|---|---|---|---|
| PHASE I: weeks 1 to 3 | Side Lying Abduction Leg Raise | 1. Lie on your side and straighten both hips and knees<br>2. Slowly raise your upper leg towards the ceiling (be sure to keep your leg in line with your body as you raise it towards the ceiling)<br>3. Return to the starting position | Repeat ___ times per limb<br><br>Perform ___ sets per session |
| | Side Lying Hip Abduction and External Rotation (Clamshell) | 1. Lie on your side and bend your hips and knees<br>2. Slowly raise your upper leg towards the ceiling, rotating your knee outward (external rotation) as you raise your leg<br>3. Return to the starting position | Repeat ___ times per limb<br><br>Perform ___ sets per session |
| | Prone Hip Extension with Bent Knee | 1. Lie on your stomach with one knee bent and one knee straight<br>2. Keeping your knee bent, lift your leg up and foot up towards the ceiling<br>3. Hold this position without lifting your pelvis or rotating your leg<br>4. Return to the starting position | Repeat ___ times per limb<br><br>Perform ___ sets per session |
| | Single Leg Stand Wall Isometric | 1. Stand with your side next to a wall (parallel to the wall)<br>2. Lift the leg closest the wall so that your thigh is parallel with the ground and your knee is bent to 90 degrees<br>3. Keeping your body still, push against the wall with the outside of your bent knee<br>4. Continue to push your knee against the wall for 10 seconds | Repeat ___ times per limb<br><br>Perform ___ sets per session |
| | Quadriped Hip Abduction/External Rotation into Abduction | 1. Kneel on your hands and knees<br>2. Keeping your knee bent, rotate your leg towards the ceiling<br>3. Slowly straighten your knee and hip<br>4. Slowly return to the starting position | Repeat ___ times per limb<br><br>Perform ___ sets per session |
| Phase II: Weeks 4-6 | Band Resisted Lateral Walk | 1. Stand with a resistive band around both ankles<br>2. Slightly bend both knees<br>3. Walk/shuffle sideways while you keep your hips, feet, and knees pointed forward. | Repeat ___ times<br><br>Perform ___ sets per session |
| | Band Resisted Backward Diagonal Walk | 1. Stand with a resistive band around both ankles<br>2. Slightly bend both knees<br>3. Keeping your knees pointed straight ahead, walk backward by taking turns moving each foot in a diagonal, backwards direction | Repeat ___ times<br><br>Perform ___ sets per session |
| | Excursions | 1. Stand on one leg with your knee slightly bent<br>2. Maintaining your balance, bend forward at your hip<br>3. Reach your hand towards the floor in the directions outlined below<br>4. Repeat for each of the arrows below<br>5. Return to the starting position<br> | Repeat ___ times per limb<br><br>Perform ___ sets per session |
| | Bridge with Alternate Knee Extension | 1. Lie on your back with your hips and knees bent<br>2. Tense your abdominal muscles and lift your trunk upward so that your trunk, torso and thighs are in line<br>3. Hold this position and straighten one knee until it is fully extended<br>4. Return your foot to the mat/floor and then lower your trunk to the mat/floor | Repeat ___ times per limb<br><br>Perform ___ sets per session |

**Appendix 1.** *Individualized exercise prescription and progression by phases (continued)*

| | Exercise | Description | Reps/Sets |
|---|---|---|---|
| Phase II: Weeks 4-6 | Anterior Diagonal Hip Strengthening | 1. Secure one end of a resistance band to table or railing<br>2. Loop the other end around one ankle and move forward until the band is taught.<br>3. Keeping knee straight, push your foot forward and inward towards your other foot<br>4. Pause and return to the starting position | Repeat ___ times per limb<br><br>Perform ___ sets per session |
| | Posterior Diagonal Hip Strengthening | 1. Secure one end of a resistance band to a table or railing<br>2. Loop the other end around one ankle and move backwards until the band is taught.<br>3. Keeping knee straight, pull your foot backwards and away from your other leg<br>4. Pause and return to the starting position | Repeat ___ times per limb<br><br>Perform ___ sets per session |
| Phase III: weeks 7-9 | Squat with Band Resisted Hip Rotation and Abduction | 1. Stand with a resistance band around your thighs, above your knees<br>2. Squat down as if you are sitting back into a chair.<br>3. As you are squatting down, push your thighs outwards against the resistance band | Repeat ___ times per limb<br><br>Perform ___ sets per session |
| | Static Lunge with Band Resistance | 1. Stand with one foot in front of the other in a lunge position<br>2. Secure a resistance band around the thigh of your front leg, just above your knee so that the band slightly pulls your thigh towards your midline<br>3. Bend both knees, dipping your body downwards towards the floor<br>4. Keep your front knee centered over the ball of your foot and do not allow your front knee to move towards your midline | Repeat ___ times per limb<br><br>Perform ___ sets per session |
| | Squat Jumps | 1. Stand with your feet shoulder width apart<br>2. Squat down as if you are sitting in a chair<br>3. Jump straight up from the squat position<br>4. During landing, bend your knees and hips back into the squat position | Repeat ___ times per limb<br><br>Perform ___ sets per session |
| | Bridge with Alternate Knee Extension | 1. Lie on your back with your hips and knees bent<br>2. Tense your abdominal muscles and lift your trunk upward so that trunk, torso, and thighs are in line<br>3. Hold this position and straighten one knee until it is fully extended.<br>4. Return your foot to the mat/floor and then lower your trunk to the mat/floor | Repeat ___ times per limb<br><br>Perform ___ sets per session |
| | Split Squats | 1. Stand in a lunge position with one foot in front of the other<br>2. Place the toe of your back foot on a step/stool/chair that it is at least 18 inches tall<br>3. Bend both knees, dipping your body downwards towards the floor<br>4. Keep your front knee centered over the ball of your foot and try to minimize side-to-side movements of your knee | Repeat ___ times per limb<br><br>Perform ___ sets per session |